4. With the author's compliments

ON THE INNERVATION OF THE LONGITUDINAL COAT OF THE SMALL INTESTINE.

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ON THE INNERVATION OF THE LONGITUDINAL COAT OF THE SMALL INTESTINE.

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In investigating the action of the longitudinal coat of the small intestine[1], it has seemed to me advisable to make trial of various methods which have at different times already been employed. The earliest method of all, that of inspection, gave admirable results in the hands of Johannes Müller, and the more modern employment of graphic methods to a certain extent only enables one to confirm many of the results obtained by him long ago. The difficulties encountered in interpreting the phenomena which direct inspection shows are, however, far from small, since the contractions of the circular coat cannot fail to make themselves apparent through the thin outer coat. It thus becomes a matter of uncertainty how far the contractions observed are caused by one or by both muscular coats.

The graphic methods which I first employed consisted essentially of some arrangement of levers, attached, by means of a thread which passed over one or more pulleys, to one end of a segment of intestine, the other end of which was made fast to a fixed point. The most satisfactory of such apparatus was a modification of Professor Schäfer's heart lever, consisting of a strip of flexible metal with a writing point at the free end, which was attached about the middle by means of a thread to one extremity of an isolated segment of intestine in such a way as to record the contractions of the longitudinal coat. By employing the small heart hooks which constitute part of the apparatus for recording cardiac contractions, and inserting the point just within the longitudinal coat, it was possible to avoid any section of the intestine or tying of ligatures round it. Another modification consisted in the employment of two india-rubber tambours arranged as in the transmission-myograph of Marey.

[1] The expenses of this research were in part defrayed by a grant from the Royal Society.

These methods all gave good enough results, and moreover enabled the contractions of the circular coat to be recorded at the same time, but I was dissatisfied with them for various reasons. First, they involved the removal of a coil of intestine from the abdominal cavity, and the placing of it in a bath of warm saline solution, or other fluid, under conditions of moisture and exposure which could scarcely be considered normal. Then, again, the segment of intestine was attached by its mesentery in such a way that the contractions must necessarily travel along the arc of a circle instead of along a straight line, and any alteration in the curvature must affect the recording lever.

More recently, I have made use of the piston-recorder described by New in the *Journal of Physiology* of May 11th, 1899, inserting it with the broad end towards the pylorus into a short segment of intestine through an incision on the side of the gut farthest away from the mesenteric attachment. The proximal end is then fixed in position by means of a single stitch passed directly through both coats of the intestine, and the opposite end of the recorder is connected by means of an india-rubber tube with a recording tambour, the segment of intestine being returned to the abdominal cavity. A further modification of the apparatus was suggested by Professor Schäfer, and consists in fixing to the broad proximal end a small perforated bead of glass, through which a pin passes transfixing also the intestinal wall on either side. This apparatus records only the contractions of the longitudinal coat, and is unaffected by any movements of the circular fibres of the intestine.

Influence of the splanchnic nerves.

The splanchnic has been generally considered to contain both motor and inhibitory fibres for the intestine, the statement that it contained motor fibres being made as long ago as 1837 by Johannes Müller[1]. The motor functions of the splanchnic have since been upheld by Schiff[2], Nasse[3], Ludwig and Kupfer[4], Ehrmann[5], Bechterew and Mislawski[6], and quite recently by Courtade and Guyon[7]. Schiff

[1] *Handbuch d. Phys. des Menschen*, I. 1837.
[2] *Lehrbuch der Phys. des Menschen*, Lahr, 1858.
[3] *Beiträge zur Phys. der Darmbewegung*, Leipzig, 1866.
[4] *Zeitschr. fur rat. Med.* 1857.
[5] *Wiener Med. Jahresbericht*, 1885.
[6] *Arch. f. Phys.* 1889.
[7] *Arch. de Phys.* 1897.

laid stress on the point that the physiological action of the splanchnic was a motor one, but that when the nerve was exhausted by too strong a stimulus its activity was diminished and inhibition resulted. Some difference of opinion has arisen among these authors as to whether the splanchnic is a motor nerve for the circular or for the longitudinal coat; this is a difficulty which can only be combated successfully by means of graphic records.

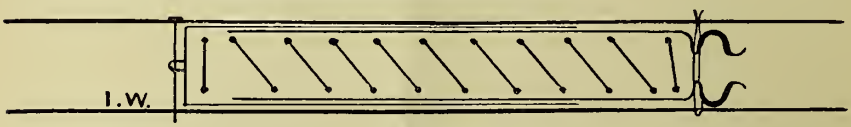

Fig. 1.

In the following experiments the splanchnic was exposed on either

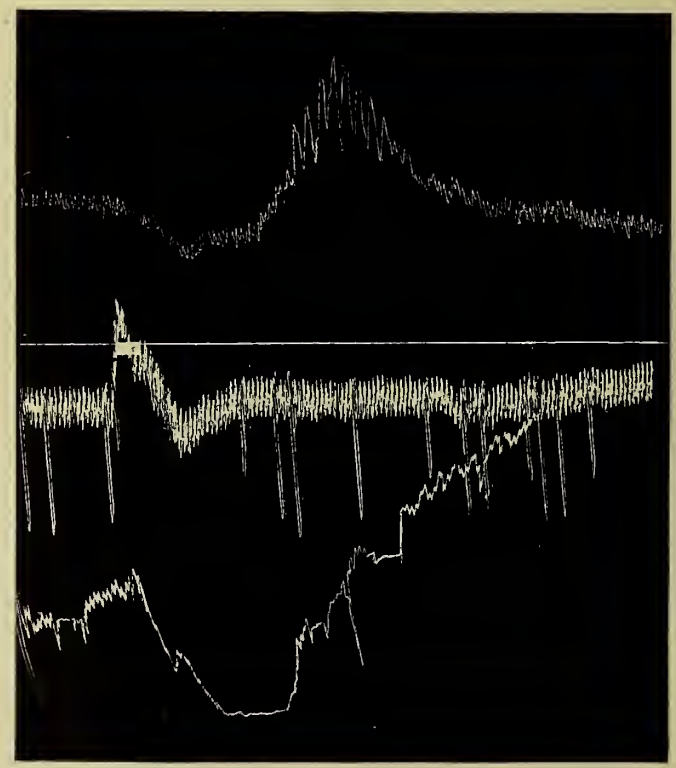

Fig. 2. Effect on the longitudinal coat of splanchnic stimulation. The upper tracing is that of the longitudinal coat, the lower tracing is the plethysmographic record of a segment of small intestine.

side by resection of one or two ribs, and then it was isolated and cut. As a rule, weak currents were employed; in order to prevent any possible implication of the vagi, these nerves were in some cases divided in the lower part of the thorax.

I have previously shown that the splanchnics contain both motor and inhibitory fibres for the circular coat of the intestine, and this seems also to be the case for the longitudinal coat. In many cases, excitation of either splanchnic with a moderate current produces inhibition more or less well marked of the longitudinal contractions, which may be followed by systolic tone of the longitudinal coat. Such systolic tone may only appear after the current has been shut off (Fig. 2), or it may be the first effect produced (Fig. 3). This is the

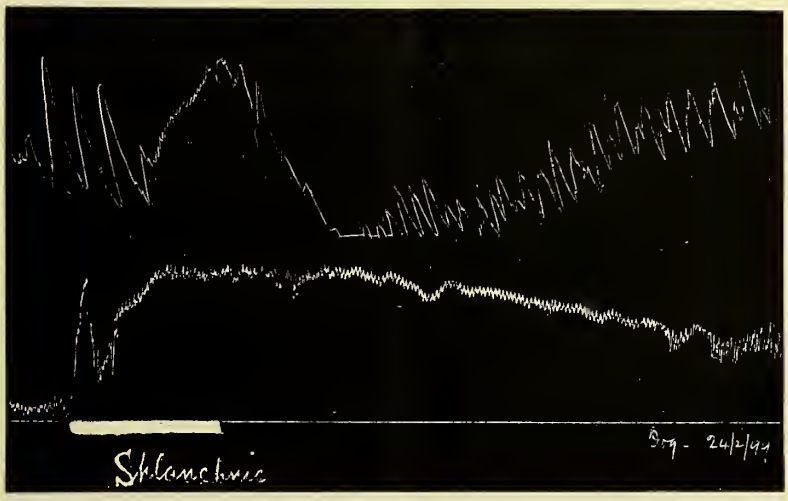

Fig. 3. Splanchnic stimulation. The upper tracing is that of the longitudinal coat.

case only when a current of moderate intensity is employed; the effect cannot be induced by weak currents. The latent period of such tonic contraction is greater than that of pure inhibition, but the duration of the systolic tone is usually less than that of the diastolic tone for the same strength of current. Fig. 4 shows the effect on both coats of the intestine at the same spot of splanchnic stimulation, the segment of intestine being outside the abdominal cavity in a bath of warm saline solution. The longitudinal contractions were recorded by attaching one end of the intestinal segment to a fixed point and connecting the opposite end by means of a thread which passed over a pulley with the

recording lever. Stimulation of the splanchnic with the coil at 8 cm. produced simultaneous systolic tone of both coats of the intestine.

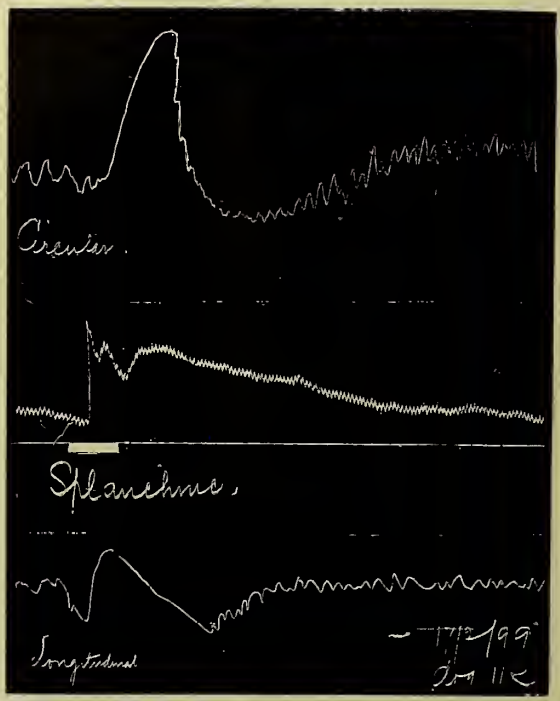

Fig. 4. Effect of splanchnic stimulation on the longitudinal and circular coats respectively of the same segment of small intestine.

In a recent paper Bayliss and Starling[1] have denied that the splanchnics contain any motor fibres for the intestine. They state that any apparent motor effect obtained on splanchnic stimulation is due not to contraction of the muscular fibres of the wall of the intestine, but to contraction of the blood vessels in the walls. If this be the case, there seems no obvious cause why these pseudo-motor effects should not be obtained with the intestine outside the abdominal cavity; the above-mentioned observers state, however, that they have never been successful in obtaining them under such conditions. It is, moreover, difficult to see how vaso-motor constriction of the intestinal vessels could cause any considerable apparent contraction of the longitudinal

[1] This *Journal*, xxiv. p. 99. 1899.

coat, even if such were possibly the case with the circular coat; the published tracings of Bayliss and Starling appear indeed to refer only to the circular coat.

Fig. 5 is a tracing of the contractions of the longitudinal coat

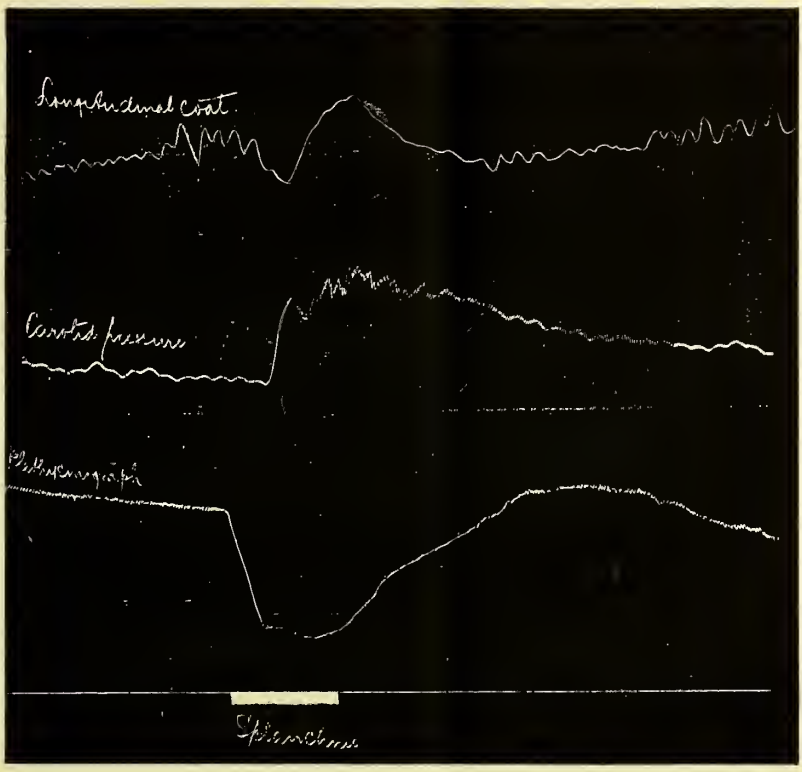

Fig. 5. Effect of splanchnic stimulation on a segment of small intestine outside the abdominal cavity.

obtained by means of the longitudinal piston-recorder from a segment of intestine outside the abdominal cavity in a bath of warm saline solution. The normal rhythmic contractions of the longitudinal coat recur at regular intervals of five seconds, and are synchronous with those of the circular coat. Moderately strong stimulation of the splanchnic caused systolic tone of the longitudinal coat of moderate extent, preceded by a short stage of diastolic tone. The plethysmographic record showed that splanchnic stimulation caused simultaneous constriction of the intestinal vessels, but it is probable that this could

give rise to but very small diminution in length of the longitudinal coat. The heart was then excised as rapidly as possible, causing the plethysmographic lever to fall very quickly until it ceased to record, and the splanchnic was again stimulated. Systolic tone of the longitudinal coat was again produced, but of less absolute extent than before, though in comparison to the height of the diminished intestinal contractions its range was not very much less (Fig. 6).

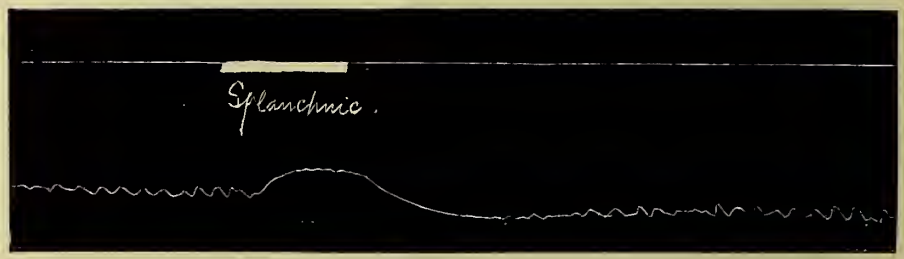

Fig. 6. Effect of splanchnic stimulation on the same segment of intestine as in the preceding figure, after rapid excision of the heart.

This experiment shows that such systolic tone of the longitudinal coat is quite independent of any constriction of the intestinal vessels.

The systolic tone of the longitudinal coat which is produced by splanchnic stimulation is best seen in the duodenum; it may be accompanied by entire cessation of the regular rhythmic contractions, or these may be superimposed on the tracing, though of diminished extent. The anæsthetic used in these experiments was ether, with or without curare; it was found that the administration of a considerable dose of morphia abolished the motor action of the splanchnic. It has been shown by v. Vamossy[1] that an intravenous dose of only 40 mg. of morphia has an inhibitory action on the intestinal contractions[2].

In those cases in which tonic contraction of the longitudinal coat resulted from splanchnic stimulation, some experiments were carried out in order to determine whether simultaneous contraction occurred at all parts of the small intestine. When the two piston-recorders were at some considerable distance from one another, excitation of the splanchnic produced in some cases contraction of both segments (Fig. 7), but when separated only by a distance of a few inches it was

[1] *Deutsch. med. Wochenschr.* 29.

[2] This may explain why Bayliss and Starling missed observing the contraction on splanchnic stimulation.

found that, though splanchnic stimulation caused contraction of the longitudinal coat of the upper segment, this was accompanied by inhibition of the lower segment.

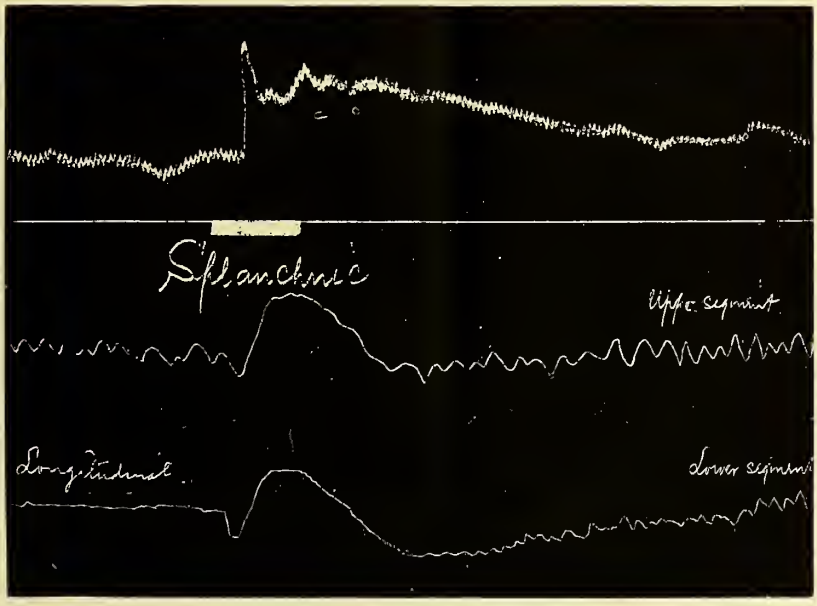

Fig. 7. Effect of splanchnic stimulation on the longitudinal coats of two segments of small intestine respectively.

When both vagi and both splanchnics had been divided, and when splanchnic stimulation caused systolic tone of both intestinal segments, a ligature was tied round the intestine midway between the two piston-recorders. After the initial inhibition, which affected both segments of intestine, and therefore travelled upwards as well as downwards, had passed off, excitation of the splanchnic with the same strength of current as before still produced tonic contraction of the segments both above and below the ligature.

Influence of the vagi.

When stimulating the vagi, the nerves were exposed in the thorax as they lie on the œsophagus. In a few cases, the nerves were stimulated in the neck, both before and after the administration of atropin. When both splanchnics had been previously divided, stimulation of the peripheral end of either vagus in the thorax with a strong

current produced an effect on the longitudinal coat very similar to that observed in the case of the circular coat, a preliminary inhibition being followed by well-marked augmentation (Fig. 8).

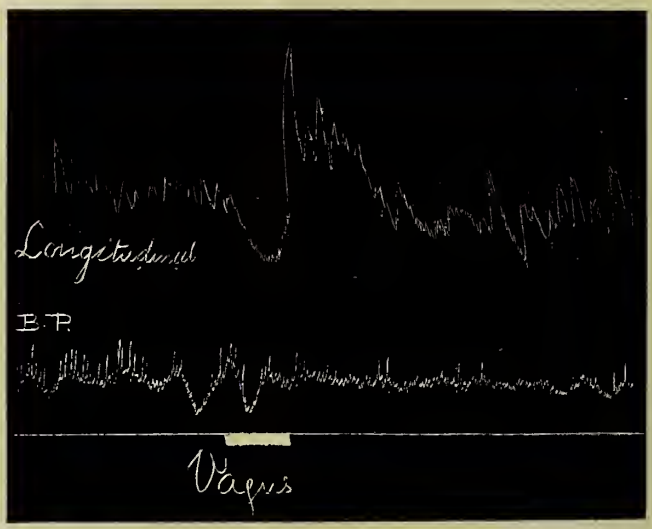

Fig. 8. Dog. Stimulation of peripheral end of cut intrathoracic vagus.

This is best seen after repeated stimulations. The latent period is somewhat greater than in the case of the circular coat, and the secondary augmentation of the longitudinal contractions is with difficulty obtained after a considerable dose of morphia has been given. Especially in the case of the duodenum is this augmentation well seen; or vagus stimulation may produce tonic contraction of the longitudinal coat of very considerable extent unassociated with inhibition. In the jejunum and ileum inhibition is more marked, and secondary increase of the longitudinal contractions is not such a prominent result of vagus excitation. Fig. 9 is a tracing taken from the second part of the duodenum, and shows tonic contraction of the longitudinal coat of considerable extent followed by increased size of the waves of contraction.

Stimulation of the central end of one vagus in the thorax after division of one splanchnic, the remaining vagus and splanchnic being still intact, produces cardiac inhibition, and in some cases contraction of the longitudinal coat. The inhibitory effect directly produced by a ligature on the segment of intestine below the ligature passes off

before long, and the effect on the longitudinal coat of stimulation of the peripheral end of the cut vagus once more appears, even though

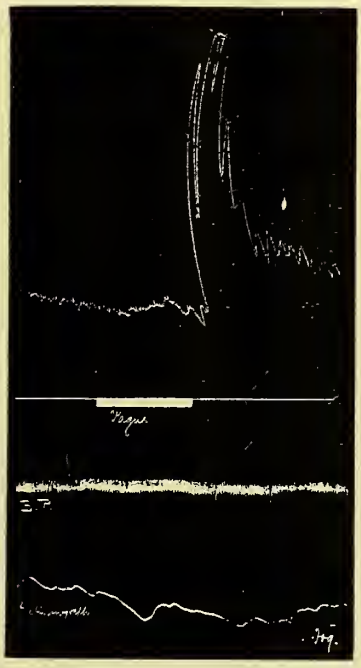

Fig. 9. Stimulation of peripheral end of cut vagus in the thorax. The lowest curve is a plethysmographic tracing of a segment of small intestine.

the ligature be but a short distance above the segment of intestine which is under observation.

Successive stimulation of vagus and splanchnic nerves.

Some experiments were performed in order to determine how far previous stimulation of one nerve affected the results which were normally obtained on excitation of another. In those cases in which after repeated stimulation of the vagus augmentation of the intestinal contractions had been produced by vagus excitation, it was found that stimulation of the splanchnic immediately afterwards produced the usual effect, though the latent period was slightly longer than usual. Fig. 11 similarly shows that, after preliminary stimulation of the splanchnic, excitation of the vagus immediately afterwards gave rise to

augmentation of the intestinal contractions to an extent quite as great as before the splanchnic effect had been induced.

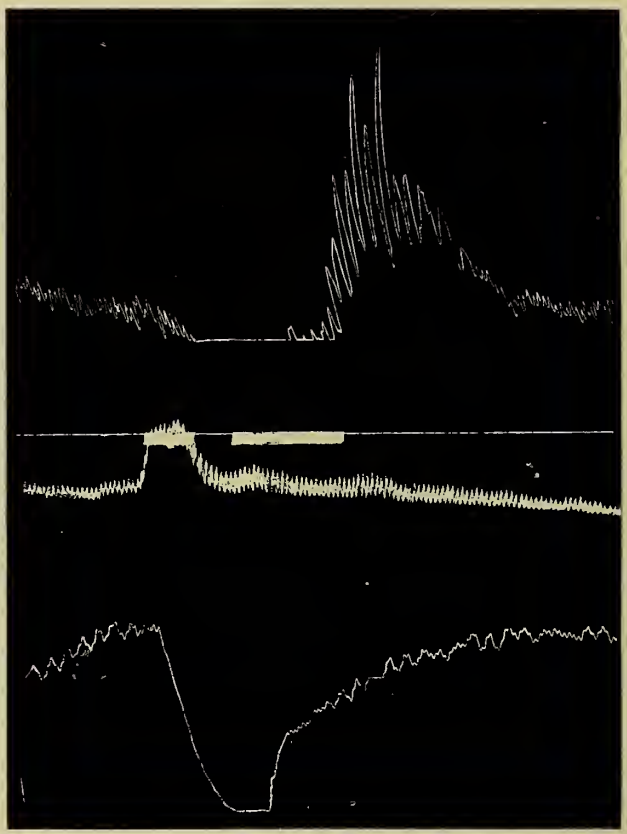

Fig. 10. Dog. Successive stimulation of splanchnic and vagus in the thorax with a moderately strong current. The upper tracing is that of the longitudinal coat, the lower tracing that of the intestinal plethysmograph.